The Influence of Gill Net Hang Ratio on the Catch of Salmon in the Fraser River

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ABSTRACT

Wilson, K.H. and J.H. Andrew. 1987. Influence of gill net hang ratio on the catch of salmon in the Fraser River. Can. Tech. Rep. Fish. Aquat. Sci. 1516: vii + 16 p.

Effects of hang ratio on relative efficiency and selectivity of Fraser River sockeye gill nets were investigated between 23 August and 23 September 1984. Three gill net panels with different hang ratios (2:1, 2.5:1, and 3:1), each with 14.0 cm (5 1/2") mesh, 60 meshes deep and 120.7 metres in length, were connected to form a test net. To minimize effects of net order and position relative to shore, panel order was selected using a randomized block design.

During 15 days of fishing, 30 sets were completed. Total catch was 570 sockeye salmon (**Oncorhynchus nerka**), 264 coho salmon (**O. kisutch**), 254 chinook salmon (**O. tschawytscha**), 66 chum salmon (**O. keta**), and 29 steelhead trout (**Salmo gairdneri**).

The catch of all species increased with increasing hang ratio. Significantly more large chinook and coho were captured with increasing hang ratio (F-test, $p = 0.05$) but the increase in catch of sockeye with increasing hang ratio was not statistically significant, (F-test, $p = 0.05$). Hang ratio had no significant effect on mean weight of fish captured, but the proportion of male chinook, sockeye, and coho decreased with increasing hang ratio.

The gill net with a hang ratio of 2.5:1 caught significantly fewer large chinook and coho salmon than the net with a hang ratio of 3:1. Further, this reduction was most dramatic for females, where the decline in catch was close to 50%. Although there was no significant reduction in sockeye catch, catches did decline by 15% between the nets with 3:1 and 2.5:1 hang ratios. A hang ratio of 2:1 further reduced catches of all species, (sockeye 15%, chinook 16% and coho 9.5%).

RÉSUMÉ

Du 23 août au 23 septembre 1984, on a étudié l'incidence du taux d'armement sur l'efficacité et la sélectivité relatives de filets maillants pour la pêche du saumon rouge dans le fleuve Fraser. Trois faces de filet maillant a différents taux d'armement (2:1, 2,5:1 et 3:1) composaient le filet expérimental; chaque face mesurait 120,7 m de longueur avec 60 mailles de profondeur (maille de 14,0 cm (5½")). Afin de minimiser l'incidence de l'ordre et de pa position du filet par rapport au rivage, on a choisi la séquence des faces selon un plan avec répartition au hasard dans les blocs.

On a effectué 30 mouillages au cours de 15 jours de pêche. Au total, on a capturé 570 saumons rouges (**Oncorhynchus nerka**), 264 saumons cohos (**O. kisutch**), 254 saumons quinnats (**O. tschawytscha**), 66 saumons kétas (**O. keta**),et 29 truites arc-en ciel anadromes (**Salm gairdneri**).

Chez toutes les espèces, les captures ont augmenté avec le taux d'armement. Un nombre nettement plus élevé de saumons quinnat et coho a été capturé en fonction de l'augmentation du taux d'armement (test F, $p = 0,05$) mais l'augmentation des captures de saumon rouge en fonction d'une agumentation du taux d'armement n'était pas statistiquement significative (test F, $p = 0,05$). Le taux d'armement n'avait pas d'incidence significative sur le poids moyen des poissons capturés mais la proportion de saumons rouge, quinnat et coho mâles a diminué avec l'augmentation du taux d'armement.

Le filet maillant à taux d'armement de 2,5:1 a capturé nettement moins de gros saumons quinnat et coho que celui à taux d'armement de 3:1. De plus, cette baisse était plus prononcée pour les femelles dont les prises ont été réduites de prés de 50%. Quoiqu'il n'y ait pas eu de baisse marquée des captures de saumon rouge, on note une baisse de 15% entre les taux d'armement de 3:1 et de 2,5:1. Une baisse encore plus marquée pour toutes les espéces a été notée avec un taux d'armement de 2:1 (rouge: 15%; quinnat: 16%; coho: 9.5%).

INTRODUCTION

The efficiency and selectivity of the British Columbia salmon gill net fleet is controlled through time, area, and gear (length, depth, mesh size, 'hang ratio' and twine type) regulations. Hang ratio is the length of web material divided by the length of the completed gill net. For example, a standard sockeye gill net in the Fraser River may have 300 fathoms of webbing hung on 100 fathoms of lead and float line for a hang ratio of 3:1). Time and area closures exploit differences in run timing and distribution to control harvest rates for the target stocks and minimize the incidental catch of others. Restrictions on net length and depth control gear efficiency, while restrictions on mesh size, hang ratio and twine type effect both net efficiency and selectivity.

In the Fraser River, net length and depth, mesh size, hang ratio and twine type are all regulated. Mesh size restrictions were modified most recently in 1981 to reduce the catch of chinook salmon during sockeye fisheries (Wilson and Pearse 1984). Hang ratio was first restricted to a maximum of 2.5:1 in 1954 and was increased to the present legal maximum of 3:1 in 1955.

Hang ratio, in conjuction with the suppleness of the web material, greatly affects a gill net's capacity to tangle fish. While fish of all sizes can tangle in a gill net, those fish which are too large to be gilled and too small to be wedged in the net are captured exclusively by the tangling action of the net. In practice, however, few fish smaller than the gill net target size are tangled.

Gill net selectivity has been reviewed by Hamley (1975) and von Brandt (1974). Unfortunately, most studies focus on gilling and wedging and rarely assess tangling of large fish in small mesh nets. Nets with high hang ratios have been shown to tangle more fish (von Brandt 1955, Hamley 1975). Thinner and more flexible twine may also tangle more fish and catch larger fish provided the twine remains sufficiently strong, but few supporting data are available. Ali and Abu-Gideiri (1984) found that nets with thin twine were more efficient. Riedel (1963) showed both gill net efficiency and the size range of tilapia (**Tilapia mossambica**) captured increased with hang ratio.

The purpose of the present study was to determine the effect of hang ratio on the relative efficiency and selectivity of gill nets commonly used to harvest sockeye in the Fraser River.

METHODS

Three gill net panels were constructed with hang ratios of 2:1, 2.5:1, and 3:1. Each 120.7 m long (66 fathom) panel was constructed with 14.0 cm (5.5 inch) mesh gill net of light green #19 multifilament nylon twine, and was 60 meshes in depth. The panels could be connected in any order.

The three-panel net was set twice daily on 15 days between 23 August and 23 September 1984, at a site in the Fraser River, upstream from New Westminster, known locally as "McAdam Drift" (Fig. 1). Fishing was restricted to days when no commercial fishing activity occurred. To reduce variability in catch due to set time and duration, the net was set just before low tide on each fishing day, and was retrieved 30 minutes after the set was completed. Net retrieval time was related to catch; set duration for each panel varied considerably between sets and ranged from 35.0 to 66.5 minutes. The average set duration over 30 sets for the

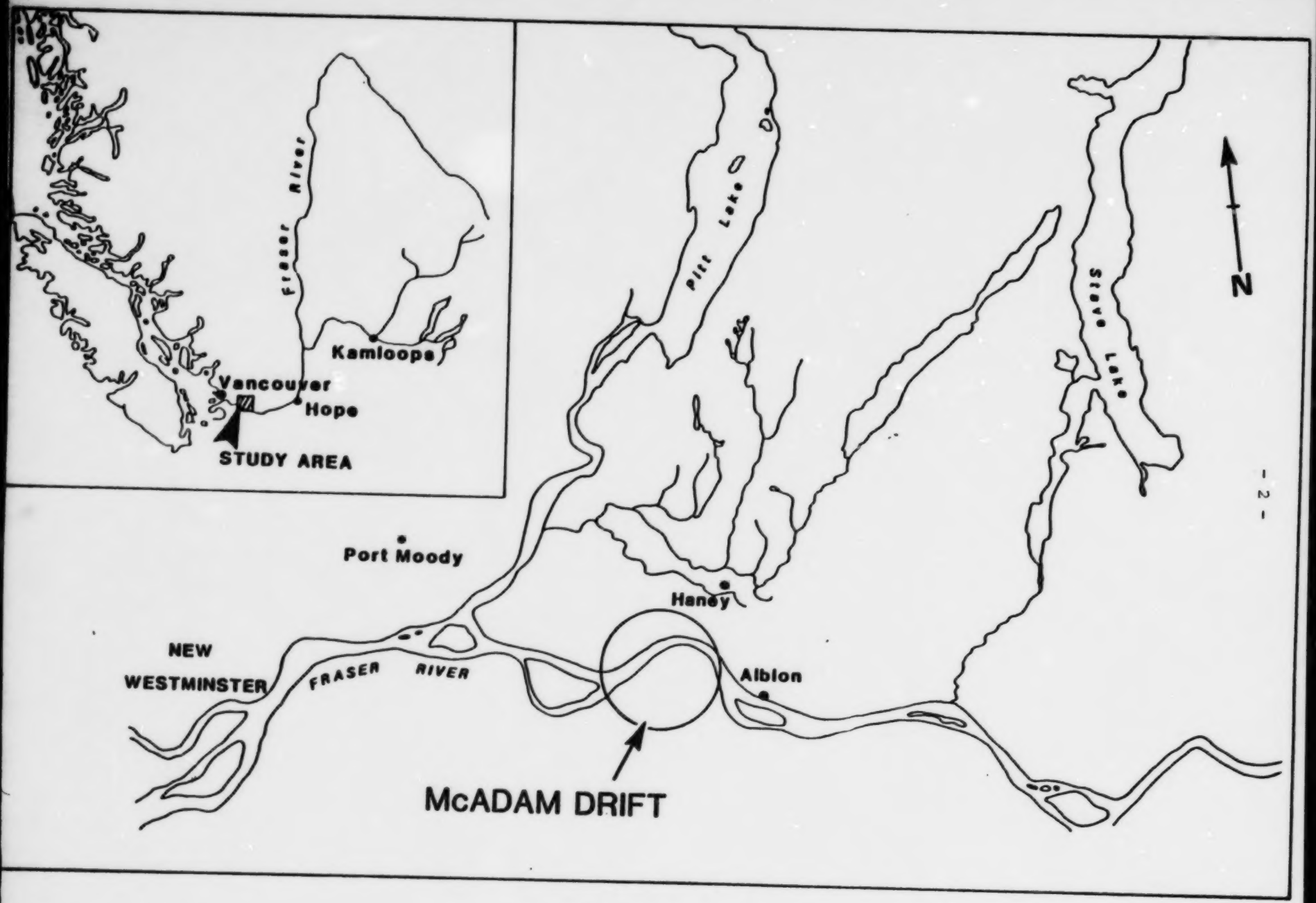

Figure 1. Map of the Lower Fraser River study area.

three panels were very similar: 47.5, 46.7, and 46.5 minutes for panels with hang ratios of 3:1, 2.5:1, and 2:1, respectively. The variation in set duration resulted from the relationship between catch and net retrieval time, since more time was required to pull the net when catches were higher.

To minimize the effects of panel position and interactions between panels, the order of the panels relative to shore was assigned using a random number table and the net was reversed on the second set of the day. Panel order was selected without replacement until all six possible combinations had been fished. In this manner, all possible combinations were fished every three fishing days.

The fish captured in each panel on each set were counted and segregated for later analysis. On completion of the set, the sex, weight, postorbital-hypural length, and mode of capture (gilled, wedged, or tangled based on location of net marks) were recorded for all chinook and coho salmon captured and for a random subsample of sockeye salmon.

In this report "male chinook" refers to males weighing 2.3 kg or more, "adult" chinook refers to all females plus large males, and "jack chinook" refers to males weighing less than 2.3 kg.

RESULTS

Numbers Captured

Five species of fish were taken in 30 sets, including 570 sockeye salmon (**Oncorhynchus nerka**), 264 coho salmon (**O. kisutch**), 254 chinook salmon (**O. tschawytscha**), 66 chum salmon (**O. keta**), and 29 steelhead trout (**Salmo gairdneri**) (Table 1). The catch of each species increased with increasing hang ratio (Fig. 2 and 3). Fig. 4 shows the percent decrease in catch with decreasing and hang ratio.

Catch per unit of effort (expressed as the catch per thousand fathom minutes of effort or KFM) for all species combined and for chinook, coho and sockeye was greatest in the panel hung at 3:1 and lowest in the panel hung at 2:1 (Table 2). To assess the relative efficiency of the nets, ANOVA was performed on catch per unit of effort for each panel. Catch of large chinook and coho increased significantly with increasing hang ratio. (ANOVA: $p = 0.05$). The increase in the catch of female chinook with increasing hang ratio was highly significant (ANOVA; $p < 0.01$); however, the catches of large chinook males, chinook jacks, and sockeye were not significantly different (ANOVA; $p = 0.05$).

Fish Weight and Length

The mean weights of chinook, sockeye, and coho salmon captured in each hang ratio are presented in Table 3.

There was no significant difference between panels in the weight of large chinook, large male chinook, female chinook, jack chinook, male or female sockeye, or coho (ANOVA; $p = 0.05$).

Table 1. Number of chinook, sockeye, coho and chum salmon and steelhead trout captured in gill nets with hang ratios of 2:1, 2.5:1, and 3:1, Fraser River, 1984.

Species	Hang ratio	Male		Female			Jack catch	Total catch[1]	% of sockeye catch
		Catch	Percent sockeye	Catch	Percent sockeye	Percent female			
Chinook	2:1	43	26.7	17	10.6	28.4	7	60	37.3
	2.5:1	47	24.9	22	11.6	31.9	11	69	36.5
	3:1	52	23.6	46	20.9	46.9	9	98	44.5
Total							27	227	
Sockeye	2:1	194		57		35.5		161	
	2.5:1	198		80		42.2		189	
	3:1	123		97		43.9		220	
Total								570	
Coho	2:1	47	29.2	16	12.4	29.6		67	41.6
	2.5:1	51	27.0	23	12.2	31.1		74	39.2
	3:1	73	33.2	50	22.7	40.7		123	55.9
Total								264	
Chum	2:1	17	10.6	3	1.9	15.0		20	12.4
	2.5:1	16	8.5	6	3.2	27.3		22	11.6
	3:1	18	8.2	6	2.7	25.0		24	10.9
Total								66	
Steelhead	2:1							7	4.3
	2.5:1							9	4.8
	3:1							13	5.9
Total								29	

1 Jack chinook not included.

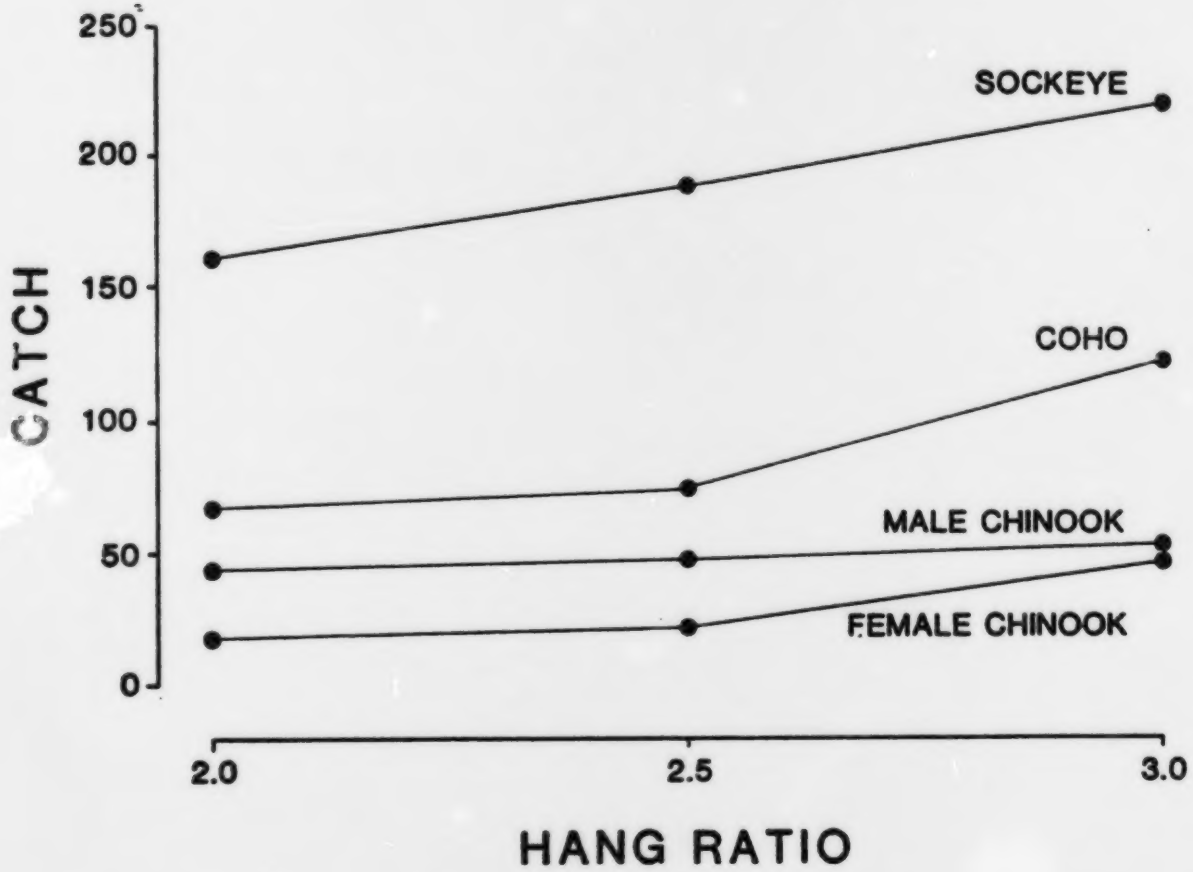

Figure 2. Catch of chinook, sockeye, and coho salmon versus gill net hang ratio.

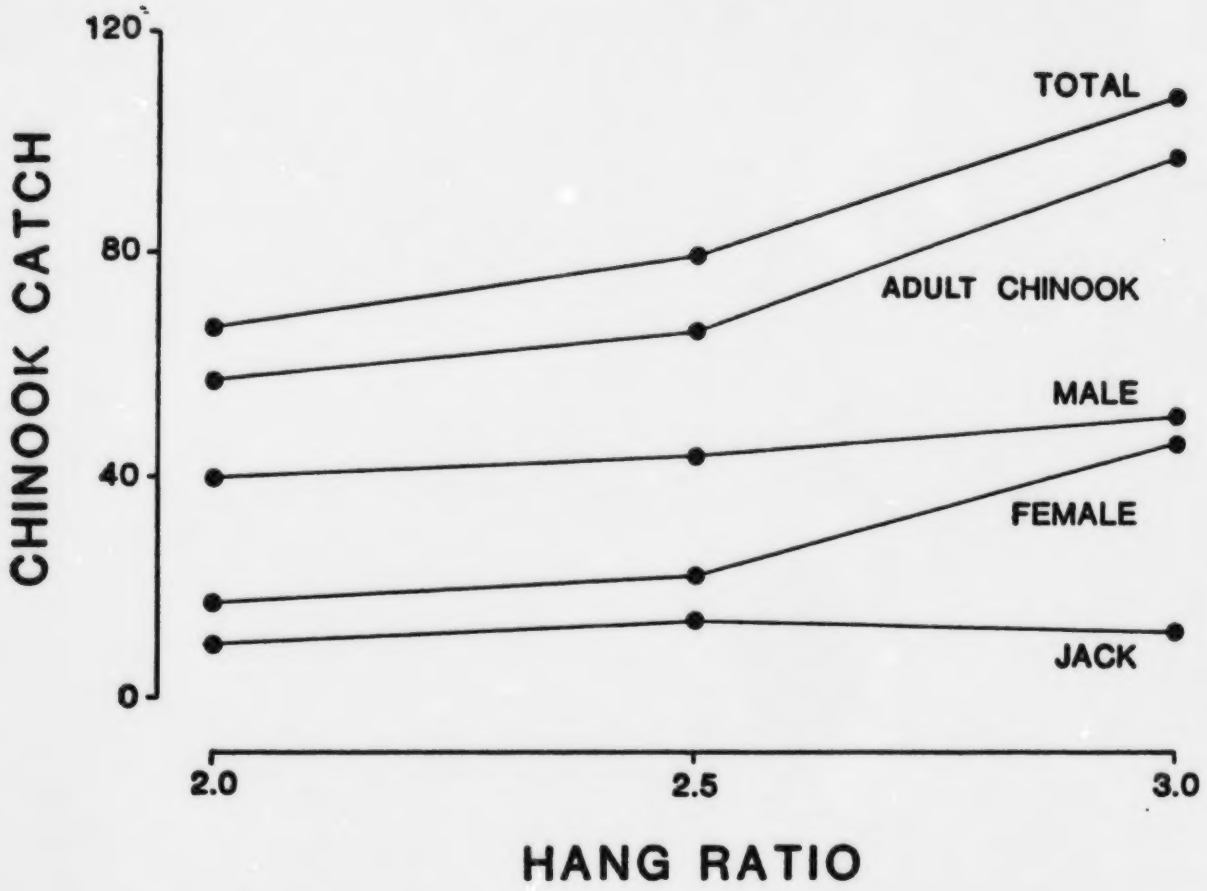

Figure 3. Catch of male, female, and jack chinook salmon versus gill net hang ratio.

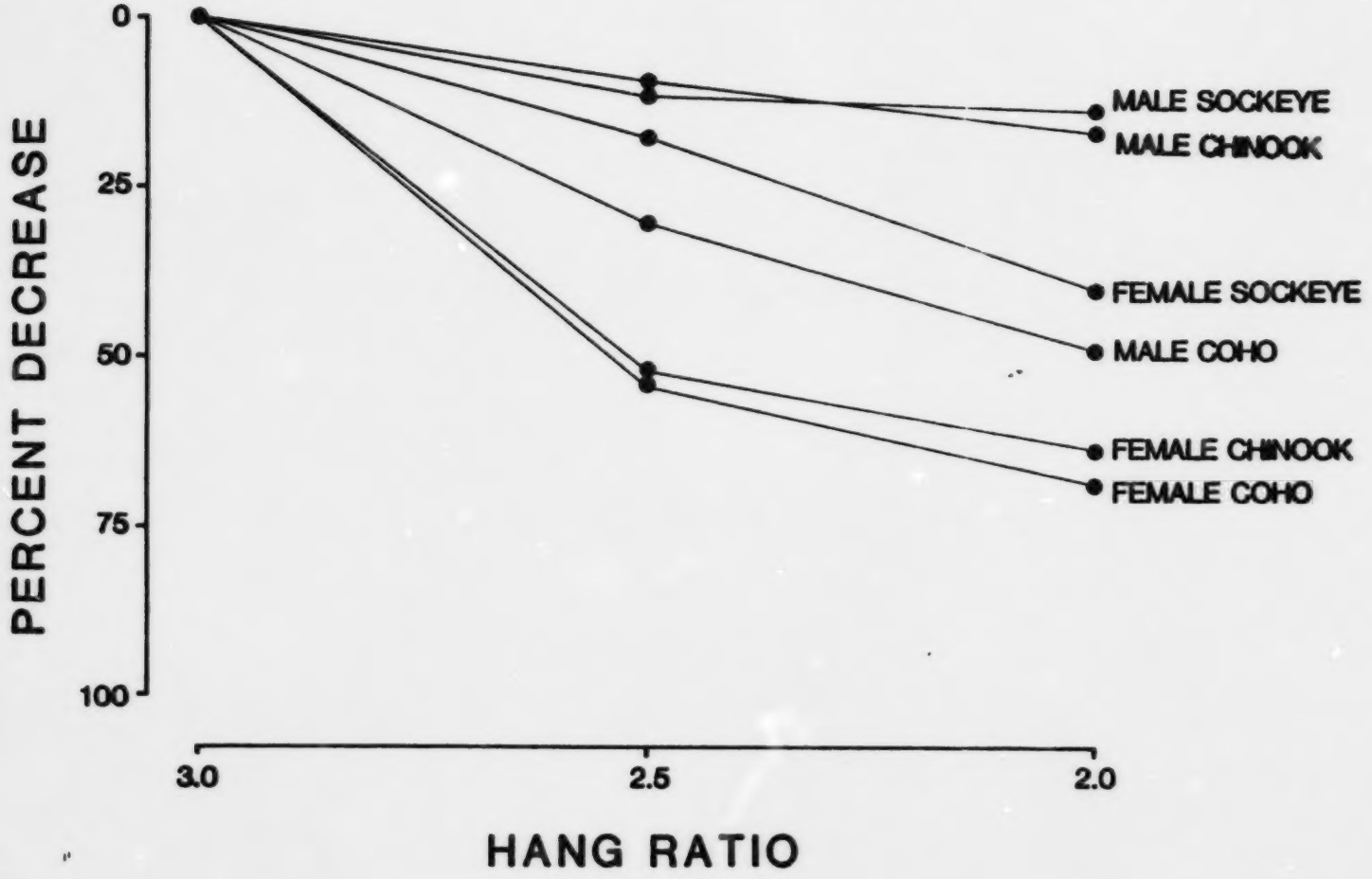

Figure 4. Percent decrease in catch of chinook, sockeye, and coho salmon captured versus gill net hang ratio.

Table 2. Mean catch of chinook and sockeye and other salmon per thousand fathom minutes of fishing effort in gill nets with hang ratios of 2:1, 2.5:1, and 3:1, Fraser River, 1984.

		Catch per KFM		
		Chinook	Sockeye	All Species
Hang ratio	2:1	0.72	1.37	3.30
	2.5:1	0.88	2.13	4.10
	3:1	1.17	2.65	5.12
Net order	2:1 in middle	0.84	2.03	3.61
	2.5:1 in middle	1.03	3.23	5.65
	3:1 in middle	0.90	0.90	3.25
Net position	Adjacent to South Shore	0.92	2.69	5.31
	Middle	0.81	1.60	3.56
	North	1.04	1.86	3.64

Table 3. Mean weights (kg) of chinook, sockeye, and coho salmon captured in gill nets with hang ratios of 2:1, 2.5:1, and 3:1, Fraser River, 1984.

Species	Hang ratio	Male	Female	Jack (males <2.3 kg)	Overall
Chinook	2:1	6.55	8.96	2.07	6.70
	2.5:1	6.26	10.23	1.85	6.75
	3:1	6.44	9.55	1.97	7.40
Sockeye	2:1	2.85	2.77	-	2.82
	2.5:1	2.93	2.77	-	2.86
	3:1	2.97	2.84	-	2.92
Coho	2:1	2.89	2.53	-	2.78
	2.5:1	2.64	2.69	-	2.65
	3:1	3.56	2.59	-	2.57

Sex Ratio

Although males comprised the greater proportion of the chinook catch in each panel, the proportion of males declined markedly with increasing hang ratio, especially from the 2.5:1 to the 3.1 panels (Fig. 5). The catch of male chinook increased from 43 to 53 from the 2:1 to the 3:1 panels while the number of females increased from 17 to 46 chinook, reducing the proportion of males in the more loosely hung nets. ANOVA of fish abundance and hang ratio revealed no significant difference in the catch of large male chinook in the three panels ($p = 0.05$), but showed a significant difference in the catch of female chinook ($p = 0.05$); however, the percentage of chinook males captured in each set was not significantly different (ANOVA, arcsin transformation; $p = 0.05$).

A similar pattern was observed in coho catch although the decline in the proportion of coho males was not as great from the 2.5:1 to the 3:1 panels. Although the proportion of male sockeye also declined with increasing hang ratio, the greatest decline was between the 2:1 and 2.5:1 rather than between the 2.5:1 and 3:1 panels.

Mode of Capture

Chinook were captured by tangling much more frequently than sockeye (Table 4). All female chinook were captured by tangling in all hang ratios, but large males, although captured most often by tangling, were gilled or wedged almost 20% of the time. Most of these fish were close to the 2.3 kg (5 lbs) cut off between adult males and jacks. Several large chinook were captured by initially becoming tangled, breaking a mesh while attempting to escape thereby creating a hole of 21 cm (8 1/4 inches), and becoming gilled. Jack chinook were gilled or wedged much more frequently than large chinook (77.8% of the time). Sockeye were most often captured by gilling or wedging (79.8 to 87.1% of the time in the panels hung at 3:1 and 2:1, respectively) and the proportion of sockeye captured by tangling increased with increasing hang ratio.

DISCUSSION

Efficiency and Selectivity

Gill net efficiency, as measured by catch per unit of effort (CPUE), can be influenced by fish abundance, net saturation, interaction between nets, net position relative to shore, and differences in net depth (related to hang ratio). Because no independent, unbiased sample of the fish exposed to the net is available, only the relative effects of hang ratio on gill net efficiency and selectivity can be assessed by this study.

Gill net efficiency declined with declining hang ratio, and, in general, the decline in efficiency was greatest for larger fish which were most likely to be tangled in the net. It is surprising that the decline in catch for coho males and females was greater than that for chinook males and females respectively, since coho are smaller than chinook and nearer to the target size for the nets. It is also interesting to note that for chinook, coho and sockeye the catch of females declined more than the catch of males. The catch of chinook and sockeye males declined very little although these fish have secondary sexual characteristics (hooked noses, protruding teeth) that should cause many of these fish to be tangled easily.

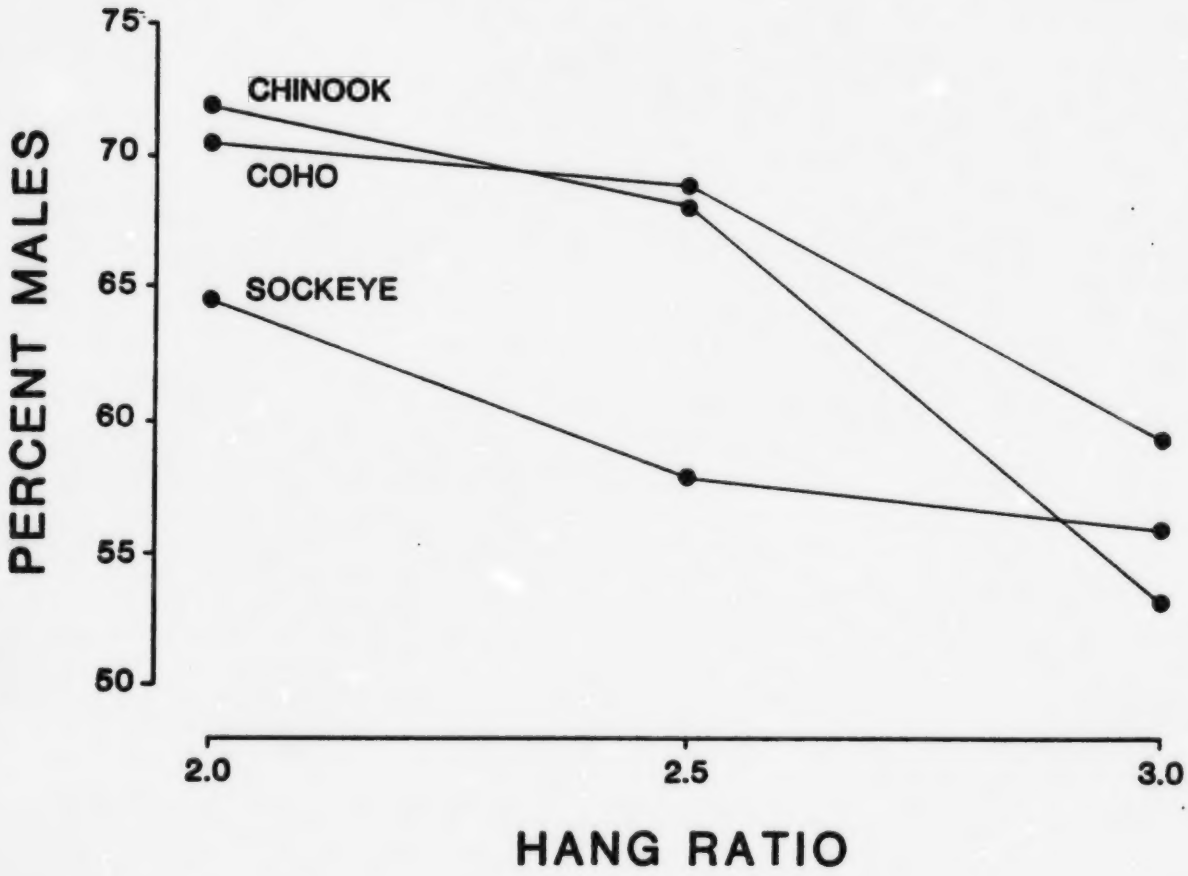

Figure 5. Sex ratio of chinook, coho and sockeye salmon captured in gill nets with hang ratios of 2:1, 2.5:1, and 3:1.

Table 4. Mode of capture of chinook, sockeye, and coho salmon in gill nets with hang ratios of 2:1, 2.5:1 and 3:1, Fraser River, 1984.

Species	Hang ratio	Males	Mode of capture: No. Tangled Females	No. Tangled Jacks	No. Gilled + wedged Males	No. Gilled + wedged Females	No. Gilled + wedged Jacks	Percent tangled Males	Percent tangled Females	Percent tangled Jacks
Chinook	2:1	33	17	1	10	0	6	76.74	100.	14.29
	2.5:1	39	22	1	7	0	10	84.78	100.	9.10
	3:1	41	46	4	11	0	5	78.85	100.	44.44
Sockeye	2:1	13	3	-	67	41	-	16.25	6.82	-
	2.5:1	22	6	-	78	67	-	22.00	8.22	-
	3:1	22	12	-	71	63	-	23.66	16.00	-
Coho	2:1	10	2	-	28	14	-	26.32	12.50	-
	2.5:1	13	2	-	38	21	-	25.49	8.70	-
	3:1	14	5	-	59	45	-	19.18	10.00	-

It would appear that reducing hang ratio has the greatest affect on the catch of those fish that are most difficult to tangle, while those fish which tangle easily continued to be caught at high rates as hang ratio decreased.

Net Saturation

Gill net efficiency decreases as fish accumulate in the web because the meshes in which fish are captured are unavailable to other fish, surrounding meshes may be distorted and less available to other fish, and fish in the net may cause other fish to avoid the gear. Gill nets may become saturated when only a small percentage of the meshes are occupied by fish (Van Oosten 1936, Kennedy 1951, von Brandt 1955), and clustering of fish may cause some parts of the net to become saturated before others (Berst and McCombie 1963). Tangled fish occupy several meshes, therefore nets that capture by tangling rather than by gilling or wedging may become saturated at lower catch levels. Saturation may affect estimates of relative selectivity where the nets being compared saturate at different levels or rates. Bias will only result if catches in each panel are significantly different or if saturation occurs at different levels in each panel.

Our data show a linear relationship between total catch and catch per unit effort (KFM) in individual sets for each hang ratio (Fig. 6). There was also a linear relationship between chinook catch per KFM and both chinook catch, and total catch. There is no evidence that gill net saturation has influenced chinook catch because catch per unit effort did not decline with increasing catch in any panel.

Net Interaction

The efficiency of panels may be biased if nets are tied together in a single gang (von Brandt 1955). Net interaction may result from competition between

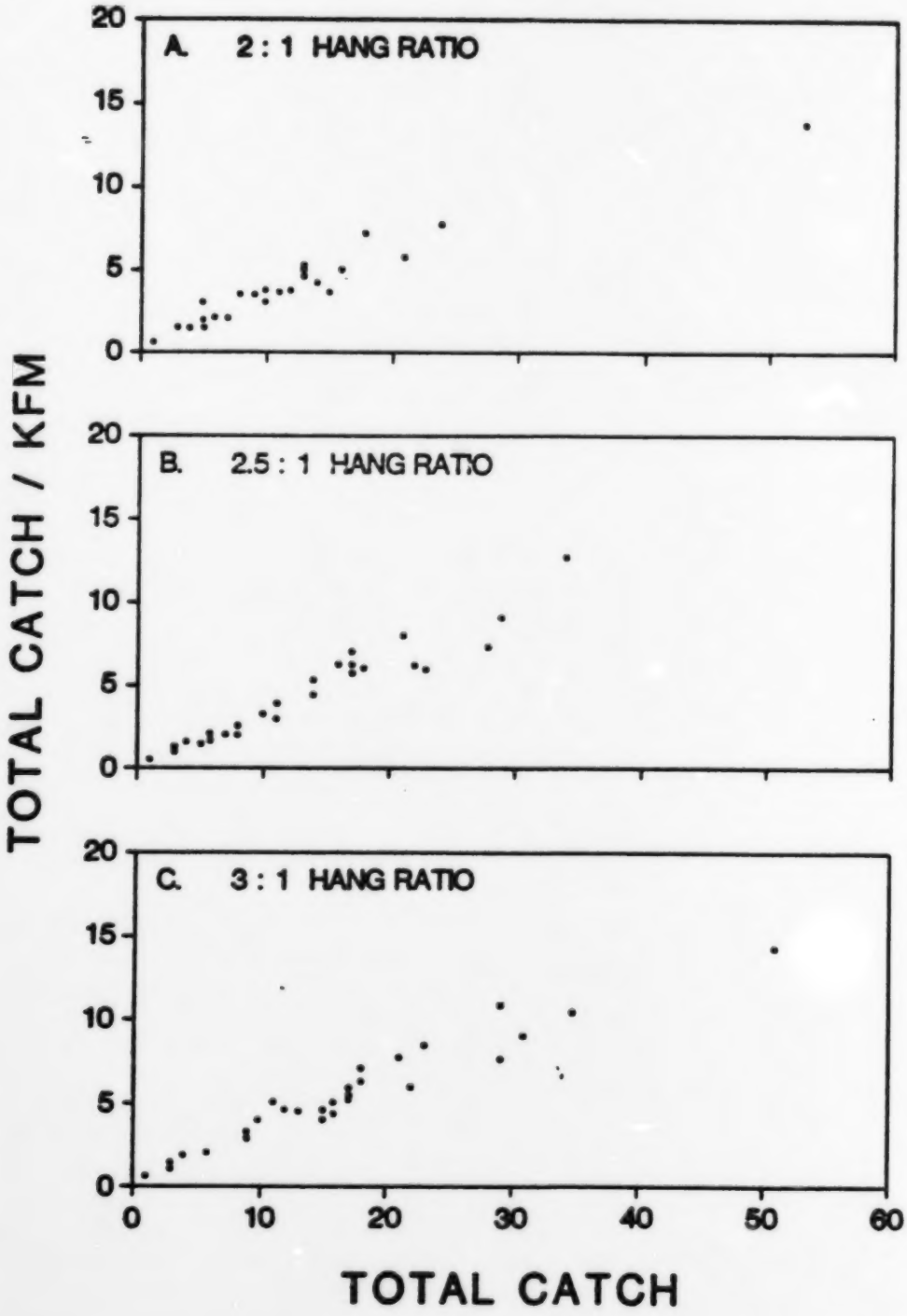

Figure 6. Relationship between total catch per thousand fathom minutes (KFM) of fishing unit effort and total catch for gill nets with hang ratios of 2:1, 2.5:1 and 3:1.

adjacent nets (Larkins 1963, 1964) i.e. fish avoiding and "leading" along nets that are inefficient for their capture until they encounter another more efficient net in which they are captured.

In this study, net order was randomized. Although the relative order of panels had no significant effect on the catch of chinook per KFM (ANOVA; p = 0.05), order of panels had a highly significant effect on total catch and the catch of sockeye (p = 0.01). The total catch was highest when the 2.5:1 panel was in the centre of the gang (Table 2). The catch of sockeye and total catch was least when the 3:1 panel was in the centre. There is no obvious reason why the net as a whole would be more efficient when the panel hung at 2.5:1 (which is of intermediate efficiency) was in the centre of the net. Because the abundance of fish in the river varied markedly between sampling days (Table 5), the high "efficiency" of the gang when the 2.5:1 hang ration panel was in the centre may have resulted at least in part because these sets were made on days when fish were most abundant.

Net Position

Bias in estimating the relative efficiency and selectivity of panels may result from their position in the gang if certain positions are favourable (von Brandt 1955). For example, the panel farthest from shore could appear to selectively capture chinook if chinook use deeper, faster water than other species.

The effect of net proximity to shore was tested using ANOVA on net position and hang ratio. There were no significant differences in the capture of chinook, sockeye, or total catch due to net position relative to shore (ANOVA; p = 0.05).

Net Depth

Although the test nets were all 60 meshes deep with 14.0 cm mesh size, mesh shape is more elongated in loosely hung nets (von Brandt 1974). As a result, the 2:1 hang ratio panel was estimated to be 58.8 cm (7%) shallower than the 3:1 hang ratio panel; however, the effect of hang ratio on net depth while the net is fishing is more complex. If, for example, a net reaches the river bottom, a deeper net will not necessarily have greater efficiency due to greater net area.

In any case, this study was designed to assess the effects of changes in hang ratio on the capture of sockeye and chinook salmon in the Fraser River gill net fishery where nets are restricted to a maximum depth of 60 meshes. These data accurately reflect the effects of hang ratio on the catch in such a fishery.

Management Implications

Restricting hang ratios during Fraser River sockeye gill net fishing to a maximum of 2:5:1 from the present 3:1 would be an effective means of reducing the incidental catch of chinook, coho and possibly steelhead particularly during periods when fishing is permitted within the river. Fishermen fishing off the mouth of the Fraser in clear water already commonly use nets hung at 2.5:1 since visability plays a major role in determining gear efficiency in these areas. Hang ratio restrictions may reduce the fleet's efficency for sockeye, but even after fishing times are increased to compensate, substantial reductions in chinook and coho catch could be realized. In addition, catches of all species will be biased

Table 5. Index of relative abundance of chinook, sockeye and coho salmon at the McAdam Drift, Fraser River, 1984. [1]

Sampling date 1984	Sockeye[2]	Adult chinook[3]	Jack chinook	Coho[2]
Aug. 23	50.5	2.2	0.0	0
Aug. 26	35.3	0.0	0.0	0
Aug. 30	104.0	2.2	0.0	0
Sept. 4	65.2	5.6	0.0	0
Sept. 5	57.5	5.5	0.0	2.3
Sept. 12	37.3	6.8	0.0	6.8
Sept. 13	47.5	13.6	0.0	3.7
Sept. 14	12.3	18.5	0.0	15.4
Sept. 17	7.1	6.8	2.2	11.8
Sept. 18	9.4	4.7	0.0	47.0
Sept. 19	0.0	4.2	0.0	40.0
Sept. 20	12.3	13.9	3.4	70.0
Sept. 21	4.4	18.5	5.9	41.3
Sept. 22	3.8	18.9	5.9	79.6
Sept. 23	5.2	15.0	6.7	117.9

1 Combined Cottonwood and Whonnock Drift test fishing data, provided by the International Pacific Salmon Fisheries Commission.

2 Sockeye and coho - 1 day lag from Cottonwood.

3 Chinook - 1-2 day lag from Cottonwood (mean of 2 days was used).

towards males and escapements towards females, increasing effective egg deposition. Our data indicate that a 30-35% reduction in the catch of female chinook and coho could be achieved with no loss in sockeye catch, and with a possible increase in the female sockeye escapement. The terminal harvest rate for sockeye could even be increased while substantially reducing chinook and coho catch.

Current mesh size restrictions conserve some chinook but reduce the efficiency of the sockeye fleet and bias the sockeye catch towards females (Wilson and Pearse 1984). Our data suggest that incidental catch of chinook can best be controlled by slightly relaxing mesh size restrictions and further restricting hang ratio.

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